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Methods for Operating a Mixed-Potential Exhaust-Gas Probe and Circuit Arrangements for Carrying Out the Methods

Ins A1> ~~State of the Art~~

The invention relates to methods for operating a mixed-potential exhaust-gas probe and circuit arrangements for Ins A2> ~~carrying out these methods in accordance with the preamble of the independent claims 1, 3, 5 and 6.~~

Mixed-potential exhaust-gas probes are utilized, for example, as gas sensors to detect the hydrocarbon concentration of the internal combustion engine or as NOx probes for detecting the nitrogen oxide component in the exhaust gas of internal combustion engines.

These probes are with respect to their configuration similar to the λ-probes and are presented, for example, in the text of Bosch entitled "Kraftfahrtechnisches Taschenbuch", 22nd edition, 1995, starting at page 490.

In known mixed-potential exhaust-gas probes, the signal is measured: as a voltage between two electrodes; via the short-circuit current between the electrodes; or, by tapping the voltage measurable between the electrodes and dropping across a resistor.

Ins A3 A3> It is an object of the invention to provide a method for operating a mixed-potential exhaust-gas probe wherein a highest possible selectivity is made possible with respect to the individual components of the exhaust gas even in the presence of sometimes very large transverse sensitivities.

Furthermore, it is an object of the invention to provide circuit arrangements which make possible to carry out the methods with a technically simple configuration and the least number of

components.

~~Advantages of the Invention~~

~~The first-mentioned task is solved by the features of claim 1.~~

By applying a constant external voltage, the probe can be adjusted to some extent to individual exhaust-gas constituents which are to be detected. The external voltage is different from the thermodynamic equilibrium voltage.

The external constant voltage is determined previously and preferably experimentally.

~~This task is furthermore solved also with the features of claim 3.~~ In this case too, the exhaust-gas probe is adjusted to a certain extent to the detection of individual gas components of the exhaust gas.

The magnitude of the current, which is to be applied to the probe ceramic, is determined experimentally.

The sensitivity of the probe can be considerably increased by the voltage or the current which is distinguished from the thermodynamic equilibrium voltage and the thermodynamic equilibrium current, respectively.

~~The last-mentioned task according to the invention is further solved by circuit arrangements having the features of claims 5 and 6.~~

A voltage-polarized current measurement (that is, a measurement of the current which drops on the electrodes of the mixed-potential exhaust-gas probe) at constant external voltage can be realized in a technically very simple manner with an inverting operational amplifier. A voltage divider is connected to the non-inverting input of the operational amplifier and one of the electrodes of the exhaust-gas probes is connected to the

inverting input of the operational amplifier. A reference resistor is arranged in the feedback loop of the operational amplifier.

A current polarized voltage measurement is made possible in a technically simple realizable manner with a non-inverting operational amplifier. The voltage measurement is a measurement of the voltage, which adjusts between the electrodes, when applying a constant current to the probe ceramic. A voltage divider is arranged at the non-inverting input of the operational amplifier and a reference resistor is arranged at the inverting input thereof. The exhaust-gas sensor is arranged in the feedback loop of the operational amplifier.

In an advantageous embodiment, switching means are provided via which switching can take place between the two circuit arrangements.

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~~Drawing~~

~~Further advantages and features of the invention are the subject matter of the following description as well as of the schematic representation of the embodiments of the invention.~~

~~The drawings show:~~

FIG. 1 is an exhaust-gas probe having a pumped reference and known from the state of the art;

FIG. 2 shows the probe voltage, which is taken off at a polarized NOx mixed potential probe, as a function of time;

FIG. 3 shows the HC transverse sensitivity as a function of the pump voltage for a mixed potential exhaust-gas probe making use of the invention;

FIG. 4 is an embodiment of a circuit arrangement of the invention for the voltage-polarized current measurement of a mixed potential exhaust-gas probe; and,

FIG. 5 shows an embodiment of a circuit arrangement according to the invention for the current-polarized voltage measurement.

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~~Description of the Embodiments.~~

FIG. 1 shows, in section, an exhaust-gas probe 1.2 on an exhaust-gas pipe of which a wall 1.1 is shown. This wall 1.1 partitions the exhaust gas of an internal combustion engine (left) from the ambient air (right). The exhaust-gas probe 1.2 includes a solid-state electrolyte 1.3 in its exhaust-gas end portion. The solid-state electrolyte 1.3 is between a first electrode 1.4 subjected to the exhaust gas and a further electrode 1.5. A reference gas volume 1.6 communicates with the electrode 1.5 and is in direct contact with the ambient air via a channel 1.9. The electrode 1.5 is connected to a measuring feedline 1.10 and the electrode 1.4 is connected to a measurement line 1.11.

For maintaining a stable reference atmosphere, it is essential that the supply of oxygen via the pump current I_P exceeds, in time average, the occurring losses of oxygen. Such losses occur perforce during the measurement of a voltage in the electrodes when the voltage measurement is based on a current measurement via a measuring resistor in a manner known per se. Typically, measurement resistors in the megaohm range are used in the range of the measurement of voltages in the order of magnitude of the output voltage of the exhaust-gas probe of 1 V. As a consequence, a measurement current flows in the microampere range. For electrolytes, this current is carried by oxygen ions from the reference volume so that the oxygen concentration in the reference gas volume reduces because of the measurement.

A measurement pulse can be so dimensioned with respect to

its height and time duration that it supplies the required pump current in time average.

The basic idea of the invention is to achieve an improvement of the gas selectivity in that a constant external potential or a constant external current is applied to the sensor electrodes (1.4, 1.5). In this way, the signal formation can be adjusted to a certain extent to individual gases and thereby the selectivity can be improved. If a constant external potential, that is, a constant external voltage is applied, which deviates from the thermodynamic equilibrium voltage, the adjusting current is measured and evaluated. If a constant current is applied, then the measurement and evaluation of the potential, which adjusts, or the voltage, which adjusts, takes place.

By applying a voltage which lies above the thermodynamic equilibrium voltage of the disturbing electrode reaction, it is especially possible to influence the course of the disturbing reaction so that no disturbing components participate in the wanted reaction.

FIG. 4 shows an embodiment of a circuit arrangement for the voltage-polarized current measurement wherein one applies a constant external voltage to the electrodes (1.4, 1.5) of the exhaust-gas probe and measures and evaluates the current dropping via the electrodes (1.4, 1.5). The applied voltage deviates from the thermodynamic equilibrium voltage. The circuit includes an operational amplifier having a feedback loop in which a reference resistance R1 is connected; that is, the reference resistance R1 is connected between the inverting input of the operational amplifier and the output thereof. The exhaust-gas probe is connected to ground at the inverting input. A voltage divider identified by R2 is connected to the non-inverting input of the

operational amplifier. A differential amplifier is arranged between the non-inverting input and the output and the output signal to ground is the measurement signal. If the internal resistance or the potential at the exhaust-gas probe changes, then the operational amplifier controls the voltage, which is present at the exhaust-gas probe, via the reference resistance R1 which acts as a feedback resistor. The signal between the non-inverting input and the output of the operational amplifier is proportional to the current which flows through the sensor and is amplified by the differential amplifier.

The circuit further includes a three-way switch S1 by means of which switching can take place to the circuit arrangement shown in FIG. 5. The circuit arrangement shown in FIG. 5 defines a current-polarized voltage measurement wherein a constant current can be applied to the probe ceramic and the voltage which adjusts can be measured and evaluated. The circuit arrangement shown in FIG. 5 distinguishes from the circuit arrangement in FIG. 4 in that the reference resistor R1 is connected to the inverting input of the operational amplifier; in contrast, the exhaust-gas probe is arranged in the feedback loop of the operational amplifier. The voltage divider R2 is connected to the non-inverting input. In this case, the differential amplifier amplifies the voltage dropping across the exhaust-gas probe and this voltage is evaluated as a measurement signal. In this circuit, a current is impressed upon the exhaust-gas probe and this current is determined only by the voltage adjusted via the voltage divider (that is, by means of the potentiometer R2) and the resistor R1. Since the exhaust-gas probe lies in the feedback of the operational amplifier, the internal resistance of the exhaust-gas probe has no influence on the impressed current.

The voltage drop across the exhaust-gas probe is measured with the aid of the differential amplifier.

As an example, FIG. 2 shows the mixed potentials of hydrocarbons (450-45 ppm) (reference numeral 1) as well as the mixed potentials of nitrogen oxides (reference numeral 2). These mixed potentials are detected by means of a voltage-polarized current measurement (see FIG. 4) for a polarization voltage of +290 mV.

If the electrode is negatively polarized, then the signal amplitude of the hydrocarbon mixed-potential formations drops with increasing negative polarization (reference numeral 1a). The nitrogen oxide signal first drops with falling polarization voltage, reverses and then increases with increasing negative polarization voltage to 100 mV for a polarization voltage of -500 mV (reference numeral 2a).

In FIG. 3, the amplitude of the hydrocarbon mixed-potential formations (transverse sensitivity) is plotted against the pump voltage or polarization voltage.

As shown in FIG. 3, no hydrocarbon transverse sensitivity is present for a pump voltage of -600 mV so that a measurement is possible of only the NOx component.